

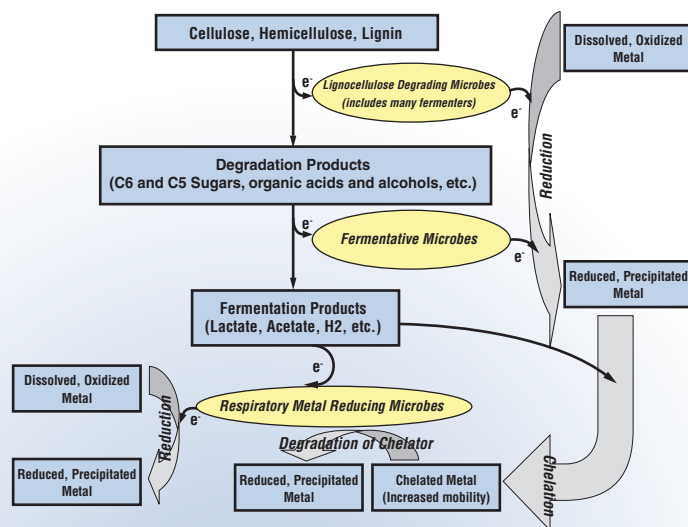
# Microbially-Facilitated Remediation of Metals and Radionuclides

Numerous waste sites across the U.S. Department of Energy complex are contaminated with metals and radionuclides. These metals and radionuclides are often the primary drivers for remedial activities at these sites. In situ methods for the remediation of metals and radionuclides are currently being developed. Fate and transport of metals and radionuclides can be directly or indirectly affected by the activity of microbes. At INL, research has focused on microbial reduction of Cr(VI) and of U(VI), which can lead to nontoxic and immobile forms. In addition, INL researchers have investigated the microbially-facilitated precipitation of minerals that can sequester radionuclides such as Sr-90 and U(VI) through coprecipitation. Considerable progress has been made in these two areas, as discussed below.

## Focus on microbial metal reduction

Hexavalent chromium [Cr(VI)] and uranium [U(VI)] contamination occur in groundwater and soil at more DOE waste sites than any other category of contaminant. Toxicity and mobility of these contaminants is highly dependent on their valence state; research has demonstrated that bacteria indigenous to soils can, as part of their normal respiratory metabolism, reduce metals and radionuclides such as Cr(VI) and U(VI). This process is important to understand because reduction of these contaminants decreases both mobility and toxicity.

Our recent research has demonstrated that a cellulolytic and fermentative bacteria, a *Cellulomonas* spp. Isolated from



**Schematic showing the hypothesized central role of fermentation bacteria like *Cellulomonas* spp. in subsurface metal and radionuclide reduction.**

Hanford sediments, can reduce and precipitate metals and radionuclides, such as Cr(VI) and U(VI), in the presence of sugars such as xylose and glucose, while producing short chain organic acids such as lactate, acetate and formate. These fermentation products can influence the mobility of metals and radionuclides through chelation (resulting in increased mobility) or by acting as carbon and energy sources for other metal and radionuclide reducing bacteria (potentially resulting in decreased contaminant mobility). Our current research, sponsored by the DOE Office of Science, is directed towards better understanding the role of fermentative bacteria in metal and radionuclide reduction. This research is designed to show that the little studied fermentative bacteria actually may be central in controlling

rates of microbial metal and radionuclide reduction in many subsurface environments.

## Microbially-mediated coprecipitation

Geochemical and microbiological approaches have been combined to resolve metal and radionuclide contamination issues. Microbial activity can indirectly affect the mobility of metals and radionuclides through coprecipitation of these contaminants in minerals such as calcium carbonate or calcium phosphates.

We are currently studying the potential for urea hydrolyzing organisms to accelerate calcite precipitation and coprecipitation of contaminants such as Sr-90. Laboratory studies have indicated the promise of this

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approach, and we are currently conducting field trials.

More recently, we have begun investigating whether microbial

hydrolysis of organic phosphate compounds can immobilize metals such as U(VI) and Sr-90 through coprecipitation in phosphate minerals. With both coprecipitation approaches, an

important goal is demonstrating that the remediation is sustainable over the long-term. Both coprecipitation research efforts are also sponsored by the DOE Office of Science.

### For more information

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### Selected Publications/Presentations/Patents

**Gerlach, R., E. K. Field, S. Viamajala, B.M. Peyton, W. A. Apel, and A. B. Cunningham.** 2011. Influence of carbon sources and electron shuttles on ferric iron reduction by *Cellulomonas* sp. strain ES6. *Biodegradation*. 22:983-995.

**Sivaswamy, V., M. I., Boyanov, B. M. Peyton, S. Viamajala, R. Gerlach, W. A. Apel, R. K. Sani, A. Dohnalkova, K. M. Kemner, and T. Borch.** 2011. Multiple Mechanisms of Uranium Immobilization by *Cellulomonas* sp. Strain ES6. *Biotechnol. Bioeng.* 108(2):264-276.

**VanEngelen, M.R., R. K. Szilagy, R. Gerlach, B. D. Lee, W. A. Apel, and B. M. Peyton.** 2011. Uranium exerts acute toxicity by binding to pyrroloquinoline quinine cofactor. *Environ. Sci. Toxicol.* 45(3):937-942.

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**Ferris, F. G., V. Phoenix, Y. Fujita, and R.W. Smith.** 2004. "Kinetics of Calcite Precipitation Induced by Ureolytic Bacteria at 10 to 20°C in Artificial Groundwater." *Geochimica et Cosmochimica Acta*, 68, 1701.

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